LUNAR BEAGLE: AN EXPERIMENTAL PACKAGE FOR MEASURING POLAR ICE AND VOLATILES BENEATH THE LUNAR SURFACE. E.K. Gibson[1], C.T. Pillinger[2], D.S. McKay[1], I.P. Wright[2], M.R. Sims[3], L. Richter[4], L. Waugh[5] and the Lunar Beagle Consortium. [1]KR, ARES, NASA Johnson Space Center, Houston, TX 77058. [2]Planetary and Space Sciences Research Institute, The Open University, Milton Keynes MK7 6AA, UK. [3]Dept. of Space Sciences, Leicester University, Leicester, UK. [4]Institute for Space Sciences, DLR, Bremen, Germany. [5]EADS-Astrium, Stevenage, UK. [everett.k.gibson@nasa.gov].

The Beagle 2 science package developed to seek the signatures of life on Mars is the ideal payload to use on the lunar surface for determining the nature of hydrogen, water and lunar volatiles found in the polar regions [1]. It could support the Space Exploration and Constellation Programs.

The Beagle 2 scientific package has been selected by NASA for the Lunar Science Sortie Opportunity (LSSO) Concept Study. The beginning of the next decade will see the launch of scientific payloads to the lunar surface to begin laying the foundations for the return of humans to the moon. Shortly thereafter, astronauts will undertake activities on the lunar surface with the ability to place scientific packages that will provide information about lunar resources and compositions of lunar materials. Important questions which must be answered early in the program concern whether there are lunar resources which would facilitate "living off the land" and not require their transport from Earth [2]. One of the promising areas are permanently shadowed regions of the moon [3]. The Lunar Beagle package is designed to be used as a separate payload on a lunar surface lander, or deployed by an astronaut, or carried by a lunar rover.

In respect of human missions, the Beagle system is analogous to the ALSEP instruments used on the Apollo missions [2]. It could operate with minimal human interaction or completely autonomously after deployment on the lunar surface.. The adaptation for sortie missions of scientific payloads developed for other planetary missions, such as the Beagle 2 science payload, has the major advantage of having already established engineering requirements, mass, power, data transmission rates, and costs [1]. A lunar modification of Beagle 2 should require decreased system overhead because of the elimination of the entry aeroshell, the vacuum system and possibly other components already budgeted for elsewhere in the carrier mission(s).

The Beagle 2 payload consisting of the Gas Analysis Package, Sample Acquisition System with subsurface sampling device, the mole, suite of scientific instruments (i.e. XRF, Mossbauer, cameras and spectrometers, power supply), was designed to operate on the Martian surface in a completely autonomous manner [1]. Its size is compatible with inclusion on a lunar rover mission. The key instrument is a magnetic sector mass spectrometer to analyze volatile species H, D/H, water abundances and other potential carbon and nitrogen containing molecules [4,5] trapped in cold regions of the moon. The subsidiary instruments for assessing elemental composition of the lunar soils and rocks, mineralogy consist of a range of spectrometers capable of fully determining rock and soil mineralogy (ages, if approperiate). The Gas Analysis Package (GAP) combined a number a number of mass spectrometric functions including static and dynamic operation. It was the first instrument with a full chance of documenting isotopic signatures in the soil and rock record. It was capable of recognizing biological intervention and geological processes. Application of the Beagle technology to answering the lunar hydrogen and H_2O question seems obvious. With the presence of a vacuum on the moon, operation of the Gas Analysis Package and the mass spectrometer should be facilitated and the payload should be able to be reduced in mass and power requirements significantly from the baseline Martian design.

Best of all, the Beagle instrument package has already been designed, built, extensively tested in the laboratory, and flight qualified for the mission to Mars. Extensive testing already done on Earth demonstrate its sensitivity, precision and other operational parameters.

One of the key goals of the Human and Space Exploration Programs is to return to the moon and have lunar surface activities that consist of a balance of science, resource utilization, and "Mars-forward" technology and operational demonstrations. Utilization of the technology developed for the Beagle 2 spacecraft fits perfectly into the goals outlined. The instrumentation onboard the Beagle 2 spacecraft with its Gas Analysis Package (GAP) and Position Adjustable Work Bench (PAW) at the end of a five degrees of freedom robotic arm which can provide science answers on the moon (for example *in situ* noble gas exposure ages) and to guide resource availability questions [1]. The primary Beagle 2 sampling device (mole) can obtain subsurface samples as deep as two meters and would be ideal for seeking out subsurface ices [1] and implanting subsurface geophysical science instruments.

The mole is envisioned to operate in two modes: (a) a subsurface sample collection device for obtaining samples for the Sample Handling and Processing Device prior to introduction into the furnaces connected to the mass spectrometer. and (b) emplacement of subsurface sensors such as seismic, heat flow, thermal conductivity and water detection; a variety of subsystems such as an onboard ion trap mass spectrometer are available for the instrumented mole.

The Gas Analysis Package can provide answers to the questions of concentrations of hydrogen [5] in the lunar polar regions, possible ice concentrations within the subsurface [3]. Importantly it can provide direct isotopic compositions to recognize the prominence of the light elements measured and their life cycles. For example, it could distinguished trapped meteoroid and cometary volatiles in the permanently shadowed regions [3]. Isotopic compositions of the hydrogen will assist in the identification of the origin of the hydrogen (possibly from the solar wind or cometary). These measurements will provide keystone data points which can be utilized in answering the lunar resource availability question and assist in the planning for "living off the land concepts" and will be of direct releance to increasing the lunar science knowledge base [2]. The mass spectrometer is capable of observing release of condensed lunar volatiles which are released at the passing of the lunar terminator along with detecting transient lunar outgassing or volatile releases from volcanic or impact events.

Given the interest in establishing permanent bases near the lunar poles, the location of choice because of the environment temperature stability and operational considerations during long duration extra vehicular activity, and because of the potential resource availablility, the Beagle 2 package should be a competitive option for the priority exploration and characterization of these important regions.

Operation of the Lunar Beagle Payload in polar regions requires unique power sources. With the shortage of the plutonium power systems, alternate power sources must be considered. Solar panels and associated battery systems are of limited use. New power supply concepts are being investigated which may offer alternatives.

In summary, the Beagle payload is the ideal suite of instruments which are at a high degree of technology readiness for answering the critical questions about volatiles in permanently shadowed regions of the moon. Beagle can provide meaningful answers to a wide variety of scientific questions about the lunar surface and the lunar transient environment. The technology is "Mars Forward" and can support any future mission to the moon, Mars and beyond.

Beagle 2 enjoys support from a consortium of university and industrial partners: Aberystwyth, Birkbeck, EADS-Astrium, DLR, JSC Houston, Leicester, MSSL, Open University (PSSRI + Earth Sciences + Chemistry), Rutherford Appleton Labs, Roke Manor Research, SEA, SSSL, SSTL with others. The potential exists for collaborative activities with, and hardware contributions from U.S. Groups.

References:

[1] Pillinger C.T. (2003), *The Guide to Beagle 2*, The Open University, Milton Keynes, UK. 222 p. p. [2] Schmitt H.H., et.al. (2000) *SPACE 2000, 7th International Conf. and Exposition on Engineering, Construction, Operations, and Business in Space*, Albuquerque, NM. Proceedings pp. 653-660. [3] Arnold, J.R.,(1979) JGR, **84**, 5659-5667. [4] Gibson E.K., Jr. and Chang S.(1992): *Exobiology in Solar System Exploration* 28-43, NASA SP-512. [5] Bustin R. and Gibson E.K. (1992) *2nd Conf. of Lunar Bases and Space Activities of the 21st Century*. NASA Conference Publication 3166, Vol **2**. 437-445.